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Assessment of the Correlation between the Quality of Building Materials and Strength of Concrete Members in the Building

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Abstract

The constituents of concrete have a significant amount of influence on the strength of concrete. Consequently, this research work addressed the use of compressive strength test to determine concrete strength. To achieve the aim, experiments were carried out on three different aggregate sizes-19mm, 16mm, and 13.2mm. The results showed the silt percent contained in each tested aggregate, 3% for fine aggregate, 1% for 13.2mm aggregate, and 0.05% for both 16mm and 19mm aggregate size. It also showed the moisture percent contained in the fine aggregate sample was 2.56%, the workability of the tested concrete of mix ratio1: $1\frac{1}{2}$ 2 was 0.95, the Impact Value (toughness) of the aggregates; 9.01% for the 13.2mm size, 7.13% for the 16mm, and 7.95% for the 19mm size of aggregate. The compressive strength test showed that the 19mm size aggregate had the highest strength after each seven days. For the test on concrete members (column), Schmidt hammer test was carried out to determine the strength and variation in the workmanship of each tested column. The result of this research work showed that the 19mm aggregate had the most strength; and that the aggregate sizes influence the strength of the concrete. The research also showed that for each concrete member there is high variation in strength due to variation in workmanship. It is recommended that columns should be tested periodically for variation in strength to avoid building collapse.

Keywords: aggregate, building, concrete, strength, workmanship.

INTRODUCTION

Concrete, according to Neville and Brooks (1993) is any product or mass made by the use of a cementing medium. The strength of a material according to Wikipedia (2010) is its ability to withstand an applied stress without failure. Wu, Jiang and Liu. (2010). Columns and footings are the main members resisting axial force and lateral seismic force. Therefore the behavior of a column has a significant effect on the whole structure. There is increase incidences of collapsed buildings and subsequent loss of lives. The growing need for safety in the construction industry led to the adoption of the research topic to ensure safety of lives and property. Non-destructive evaluation techniques are often applied to estimate the safety and the performance of current state of concrete structures (Ohno, and Ohtsu. 2010). This research addressed the issue of failure in concrete members.

This study assessed the correlation between the quality of building materials and strength of concrete members in the building, using Covenant University, Ota as a case study. It determined the influence of quality of constituent materials on the compressive strength of concrete and strength of concrete members in the building. The only concrete member studied is the concrete column and the materials being fine aggregate, coarse aggregate, water, and reinforcement; but the scope of the project does not include reinforcement. The objectives of this research are to: assess how the quality of each selected building material affects the strength of concrete members, use of compressive strength test to determine concrete strength on a selected aggregate sample size, assess the strength of concrete members with the use of the Schmidt hammer, and test the variation in the strength and workmanship of tested columns using standard variation.

The research involved laboratory experiments on compressive strength test of concrete cubes of different aggregate mixes to determine the difference in strength as a result of the mix based on BS EN12350-2 (2000) and BS EN12390-3 (2002). The study is significantly important to ensure the safety of buildings for continuous inhabitation. As the issue of safety is paramount in the building industry, this research aims to create awareness on faulty concrete members and identify the extent to which the members can withstand the load on the building. The findings of this study will provide education on the importance of aggregate strength in determining the ultimate stability of the building.

LITERATURE REVIEW

Concrete as a composite material consists of filler and binding material where the filler materials are fine or coarse aggregate and binding materials are cement paste. Aggregate is such important matter in concrete that maximum properties and workability of concrete are directly changed with the properties of aggregates (Muhit, Haque, and Alam, 2013) (Ameh,Ajaja and Ogunde 2015). Cement and water are the only two chemically active elements in concrete. Typically the normal water-cement ratio ranges from 0.35 to 0.45 but smaller w/c ratio results in stronger concrete.

After cement, water is the most important element in concrete governing all the properties of cement concrete like durability, strength and water-tightness. The lower the ratio is, the higher the final concrete strength. The minimum water-cement ratio of 0.3g is required to ensure that the water comes in contact with all cement particles thereby resulting in complete hydration. As the amount of water increases the water/cementitious ratio also increases, producing concrete of

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inferior quality.

Gartner and Macphee (2011) explained that cement used in construction is characterized as hydraulic or non-hydraulic. Cements are used for varying purposes, such as binding sand and gravel together to form concrete, for uniting the surfaces of various materials, or for coating surfaces to protect them from chemical attack. According to Mehta and Monteiro (1993), the properties of aggregate that affect concrete particles include the size, shape, and texture of the aggregate. The ACI-American Concrete Institute (2007) also highlighted the effects of harmful substances in aggregates some of which include silt, clay, lignite, and other lightweight and soft particles. It affects the workability, paste demand, and initial strength (Paulo Monteiro, 2006). The characteristics of the aggregate influences the water demand of the concrete (Hudson, 2003). Poorly shaped (i.e. high angularity or elongated) sands in concrete have a much greater total effect on concrete quality and workability than do poorly shaped coarse aggregates because of the relationship between particle size and surface-area-to-volume ratio (Hudson, 2003).

Ahmad and Saeid Alghamdi (2012) stated that if aggregates are dense and strong, the properties of concrete are governed by the quality of the paste, and shape, surface texture, maximum size, and grading of the aggregates. Some properties such as mineralogy, surface area, surface texture, particle size and shape, elastic modulus, strength, grading and water absorption may have a significant effect on the performance of concrete, Mohammed, Salim, and Said (2010). While choosing the maximum size of aggregate it should not be greater than one-fourth of the minimum thickness of the structural member. Anik Budiati (2013) concluded in his research work that 19mm as aggregate's maximum size can be used for asphalt concrete mixture. Rough-textured and elongated particles require more cement paste to produce workable concrete mixtures, thus increasing the cost (Paulo Monteiro), after much experiment, Jian, Lin, and Chang (2005) concluded that flat and elongated particles tend to break during mixing and under traffic, have lower compatibility, and have higher breakage compaction. Oduroh *et al*. (2000) showed that the percentage of crushed coarse particles had a significant effect on laboratory permanent deformation properties. A higher aggregate modulus will result in concrete having a higher modulus; a lightweight aggregate will have a lower modulus than the mortar paste. Likewise a strong aggregate will produce concrete that is stronger than the mortar paste. In tests, concrete containing a higher percent of coarse aggregate results in a higher elastic modulus. This is due to the aggregate being stronger than the mortar.

The most important mechanical properties of concrete are its compressive strength, tensile strength, and modulus of elasticity. The term concrete strength indicates the uniaxial compressive strength of concrete (Atilim University). The factors affecting concrete strength include the speed of loading that is the higher the loading rate the higher the measured strength will be; Size of specimen, the smaller the specimen, the higher the measured strength. In a bigger specimen, the chance of having defects such as voids, local cracks, etc. is higher.

MATERIALS AND METHODS

MATERIALS

Ordinary Portland Cement (OPC) with the trade name Dangote Cement was obtained from

Ogun state which conforms to the physical properties of Type I Portland cement as stated in BS

EN 197-1 and certified by Standard Organisation of Nigeria (SON, 2003) was used as the binder.

Fine aggregate and coarse aggregate were obtained from Tipper garage, Ijako in Ota, Ogun state which conforms to the expected minimum standards for fine aggregate as stated in BS EN 933-1, 1997. Clean water, free from particles and good for drinking as specified in BS EN 1008 (17) was used for the mixing. The equipment used for the experimental process include: Sieves of different diameter, Weighing balance, Impact value apparatus, Compressive strength testing machine, Slump test apparatus, Moisture content apparatus while the tools used are shovel, hand trowel, head pan, wheel barrow, bucket, e.t.c.

RESEARCH METHODS

The research is purely experimental, which involves laboratory tests and analysis. The experiments that were undertaken included the compressive strength test of concrete. This involved molding of forty concrete cubes with different aggregate mix to identify the different compressive strength of all cube samples. The moulds were made of timber of dimension 100mm x 100mm x 100mm each. It also involved the use of the Schmidt hammer to find the strength of already existing concrete members. Different mix ratios were used as samples, to determine how mix ratio affects the strength of a building. . In order to achieve maximum concrete strength, concrete cube was cured and crushed at intervals of seven days (7), that is seven days (7), fourteen days (14), twenty-one days (21), and twenty-eight days (28). The moisture content of the fine and coarse aggregate were determined by means of the oven-dried method according to BS EN 1097-5(2008). Known weight of aggregate was oven-dried for 24 hours at a temperature above 100°C (105°C), the weight was then taken

EXPERIMENT TEST RESULTS

Silt Content Test

Table 1: Silt Content of aggregate samples

Aggregate size	19mm	16mm	13.2mm	Fine aggregate
Soil (ml)	100	100	100	130
Volume of water (ml)	200	200	200	200
Silt content (ml)	0.05	0.05	1	3

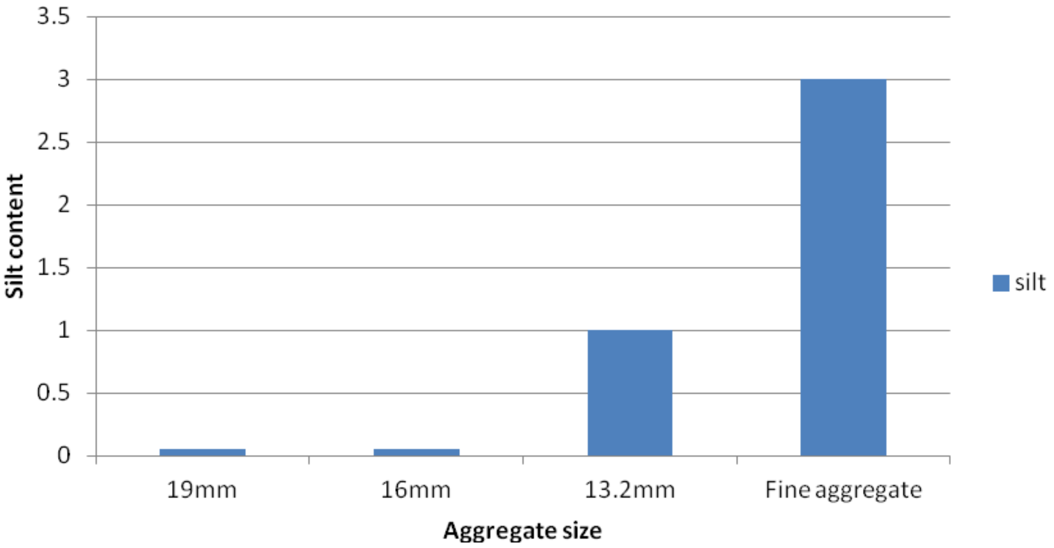

Figure 1. Bar Chart showing silt content of aggregate samples

The result shows that fine aggregate has the highest amount of silt contained in it, while the higher sized aggregates had the least amount of silt. The fine and coarse aggregate sample shown in fig.1 conforms to the ASTM C 33-01 code that states that the allowable limit for silt content in aggregate is 3%.

Table 2. Summary of Result of the Aggregate Impact Value (AIV) on 13.2mm, 16mm and19mm aggregates

Type of aggregate	The Aggregate Impact Value (AIV)
13.2mm aggregate	9.01%
16mm aggregate	7.13%
19mm aggregate	7.95%

The coarse aggregate sample shown in table 2 conforms to the BS 812-112 code that states that the AIV of the aggregate should not be more than 30%.The results show that aggregate size 13.2mm has the most toughness or crushing strength value than the 16mm aggregate and 19mm aggregate size.

Moisture Content Test

Table 3: Fine Aggregate Sample

Identification	Empty cylinder (m_c)	Empty cylinder + 40kg of moist fine agg. (m_1)	Mass after drying (m_2)
C10	0.034kg	0.074kg	0.074kg
C17	0.038kg	0.078kg	0.076kg
C4	0.038kg	0.078kg	0.076kg
A2	0.036kg	0.076kg	0.074kg
C	0.036kg	0.076kg	0.074kg
C3	0.034kg	0.074kg	0.074kg
Average	0.036kg	0.076kg	0.075kg

wc (water content) $= \frac{M_1 - M_2}{M_2 - M_c}$, $= \frac{0.076 - 0.075}{0.075 - 0.036}$ x 100 = 2.56%

The moisture content of the fine aggregate sample shown in table 3 is 2.56% and conforms to the specification in BS EN 1097-5 (2008).

Compacting Factor Test

C.F $= \frac{weightofpartiallycompactedcylinder - weightofemptycylinder}{weightoffullycompactedcylinder - weightofemptycylinder}$

$$\frac{w_2 - w_1}{w_3 - w_1}$$

Weight of empty cylinder (w_1) = 6kg; Weight of partial compaction= w_2

Weight of full compaction= w_3

Table 4: Compacting factor values for freshly mixed concrete.

Weight	Mix proportion	w/c ratio	Degree of workability
w_2	1:1$^1/_2$:2	0.65	17.4kg
w_3	1:1$^1/_2$:2	0.65	18kg

C.F $= \frac{17.4kg - 6kg}{18kg - 6kg}$ = 0.95

The compacting factor value, degree of compaction or workability for the tested fresh concrete sample above is 0.95, which is considered a high workability

Compressive Strength Test

Concrete mix ratio: 1:2:4; Cement: 5kg; Fine aggregate: 10kg; Coarse aggregate: 20kg

Water-cement ratio: 0.65

Table 5. Summary of 7, 14 &28-days compressive strength of molded concrete cubes

Aggregate size	Average compressive strength of molded concrete cubes (N/mm^2)			
	(7days)	(14days)	(21days)	(28days)
13.2mm	5.86	7.75	13.81	16.58
16mm	5.83	7.63	13.57	16.26
19mm	5.89	7.91	13.92	16.83

The compressive strength of the cubes as shown in table5 indicates that aggregate size 19mm has the highest strength while aggregate size 16mm has the least strength. This indicates that the 19mm size aggregate has the most cohesion than either 16mm or 13.2mm aggregate

Table 6. Summary of Result of Schmidt Hammer Test on Columns at Dorcas Hall

Different points on the column	column 1	column 2	column 3	column 4
1	18.2	20	17.8	16.7
2	22	18.3	23.2	27.2
3	22.8	17.9	14.4	34.4
4	12.3	15.2	22.4	28.1
5	22.7	17.1	20	20.3
6	22.9	16.3	17	22.3
7	18.4	16.6	19.6	26.4
8	16.1	13.7	23.3	13
9	16.1	18.6	21.7	15.2
10	17.9	14.1	20.9	21.8

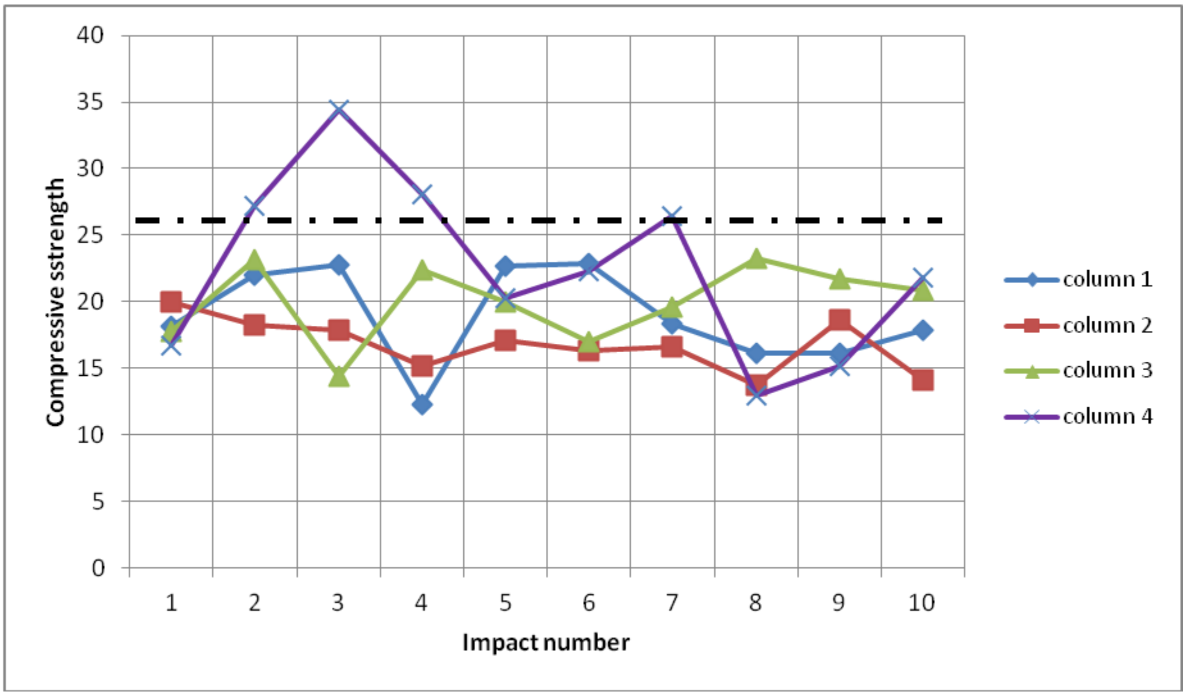

Figure 2. Graph showing difference of strength in each individual column

This result shows that the tested column is less strong than the average strength of column signified by use of the dotted line, 25N/mm^2, hence there is possibility of the future failure of the column.

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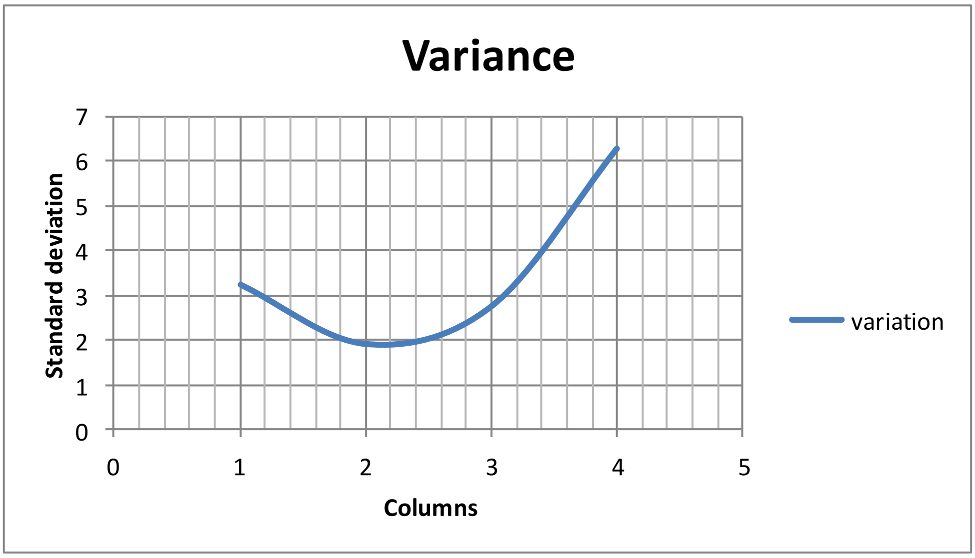

Figure 3. Graph showing the variation in the workmanship of each individual column

Table 7: Summary of Result of Schmidt Hammer Test ongoing columns in Covenant University.

Different points on the column	column 1	column 2	column 3	column 4
1	22.00	19.20	22.10	23.50
2	19.70	24.20	19.70	20.90
3	18.30	22.40	22.30	25.60
4	22.50	19.40	23.00	23.50
5	23.60	23.20	21.30	19.70
6	18.40	19.70	24.40	20.90
7	27.60	19.50	16.30	18.50
8	23.00	20.20	17.30	25.70
9	20.30	22.20	23.20	20.40
10	21.20	17.60	19.20	18.80
Average	21.66	20.76	20.88	21.75

The graph in figure 3 shows that the fourth column has the highest variation while the second column has the least variation in workmanship. This shows that the inherent constituent of the fourth column has the most variation-concrete mix, water-cement ratio. etc.

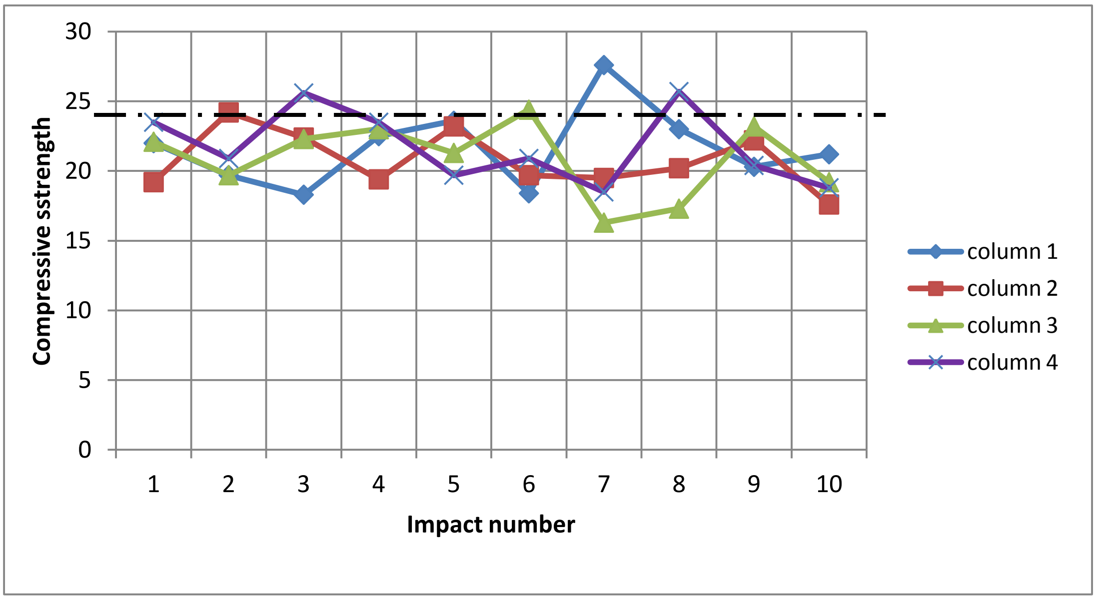

Figure 4: Graph showing difference of strength in each individual column

This result shows that the tested column has met the average strength of column signified by use of the dotted line, 25N/mm^2, therefore there is limited possibility of failure to occur in the column in the future.

The graph in figure 5 shows that there is little variation in the workmanship of each individual column, therefore the conclusion that the components of the columns are within the same range.

After testing for the variation within each column as shown in figure 4 and figure 5, the results show that the building with the most variation, that is the existing building are also shown in table7 .Fig.5 has the least strength compared to the existing building columns which had little variation.

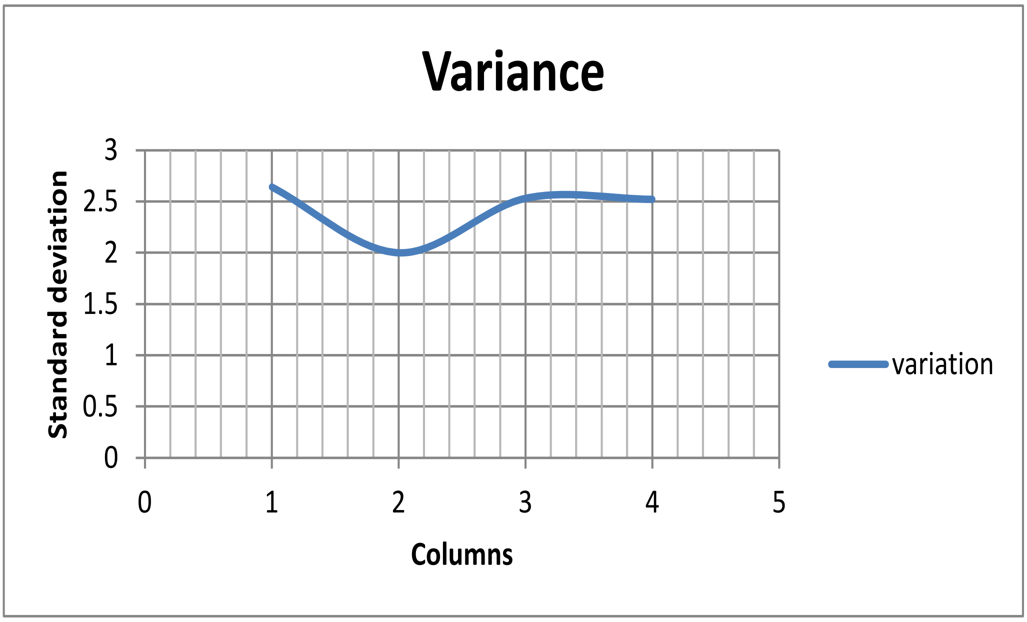

Figure 5: Graph showing the variation in the workmanship of each individual column

SUMMARY OF FINDINGS

The research work shows that aggregate size 13.2mm and 19mm have the highest compressive strength and toughness, hence they are the most suitable aggregate sizes, as regards this experiment, for construction work.

The research work affirmed that the aggregate with the highest size had the most strength as the days progressed, that is the strength did not falter from the day it was cast to the day it was crushed.

CONCLUSION AND RECOMMENDATION

- The results show that the selected aggregate sizes of aggregates are exceptionally strong and will positively influence the strength of concrete.
- Compressive strength of the tested sizes showed increase when increasing the maximum size of coarse aggregate.
- The results indicated that the compressive strength was significantly influenced by the degree of compaction of the aggregates.
- The results showed that variation in workmanship influences the strength of concrete columns as it was observed that the average strength of the columns with the least variation was higher than the columns with higher variation.
- Columns should be tested periodically for variation in strength in order to know if failure will occur in the future to avoid building failure.
- All cements used should have their expiry date stated and should be well kept so that their strength will not diminish.
- All materials to be used should be tested for conformance to relevance standards like the ASTM, and B.S code.

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